around 700 or 800 F the coal particles become plastic, the degree of plasticity varying with the type of coal.

A rapid evolution of the combustible volatile matter occurs during and directly after the plastic stage of the coal. The distillation of volatile matter continues above the plastic zone where the coal is coked. The strength and porosity of the coke formed will vary according to the size and characteristics of the coal used. While some of the ash fuses into particles in the surface of the coke as it is released, most of it remains on the hearth or grates and as this ash layer becomes thicker with time, that portion exposed to the higher temperatures surrounding the retort normally fuses into a clinker. The temperature attained in the fuel bed, the chemical composition and homogeneity of the ash, and the time of heating are factors which govern the degree of fusion.

Most bituminous coal stokers of Classes 1, 2 and 3 operate on the principle of the removal of the ash in this clinker form. Clinker tongs are provided to facilitate removal of the clinker on the smaller models.

There are a number of factors which materially affect the burning rate and the combustion results obtained with automatic stokers, the most important of these being the type and design of stoker, the characteristics of the fuel, and the manner in which the stoker is installed and operated.

Furnace Design

Due to the wide differences in stoker, boiler and furnace design, and fuel burning characteristics, it has not been found practical to establish fixed rules for the proportioning of furnaces for automatic coal stokers. It is, therefore, essential that an experienced stoker installer give careful consideration to these factors when applying the equipment.

The *Stoker Manufacturers Association* has published standard recommendations on setting heights for stokers having capacities up to 1200 lb of coal per hour.[2]

The empirical formula for determining these setting heights are:

For burning rates up to 100 lb coal per hour

$$H = 0.1125B + 15.75 \quad (1)$$

For burning rates from 100 to 1200 lb coal per hour

$$H = 0.03\,B + 24 \quad (2)$$

where

H = minimum setting height, inches.
B = burning rate coal per hour, pounds.

In considering these recommendations, it should be clearly understood that they show merely the average recommended minimum. There are many factors affecting the proper application of stokers to various types of boilers and furnaces and in many instances greater or less setting heights may give far better performance than the average values that are shown. They cannot, therefore, be used as arbitrary values in specifying stoker settings, and may be varied considerably by the installer based on

[2]Minimum Setting Heights. Copies of this standard may be obtained from the *Stoker Manufacturers Association*, 307 North Michigan Ave., Chicago, Ill.

experience with a particular stoker equipment, the type of coal that is to be used, and the construction of the boiler or furnace.

Combustion Adjustments

The coal feeding rate and air supply to the stoker should be regulated so as to maintain as nearly as possible an ideal balance between the load demand and the heat liberated by the fuel. Under such conditions no manual attention to the fuel bed should be required, other than the removal of clinker in stokers which operate on this principle of ash removal.

As in all combustion processes, the problem of maintaining the correct proportions of air and fuel is of utmost importance. It is desirable to supply a minimum amount of air required to properly burn the fuel at the rate it is being fed to the furnace.

While there may be only slight variations in the specified rate at which the coal is being fed to the furnace, due to variations in the size or density of the coal being used, there may be wide variations in the rate of air supplied as the result of changes in fuel bed resistance. These changes in resistance may be caused by changes in the porosity of the fuel bed due to variations in size or friability of the coal, ash and clinker accumulation, and variations in depth of the fuel bed. Because of this variable fuel bed resistance, many of the bituminous stokers, even in the smaller domestic sizes, incorporate air controls which automatically compensate for these changes in resistance and maintain a constant air fuel ratio.

It is also desirable on most stoker installations to provide automatic draft regulation in order to reduce air infiltration and provide better control during the banking or off periods of the stoker. The efficiency of combustion may be determined by analyzing with an Orsat apparatus the gases formed by the combustion process. With this equipment the percentage by volume of carbon dioxide (CO_2), oxygen (O_2), and carbon monoxide (CO) in the flue gases may be obtained. The percentage of CO_2 indicates the amount of excess air supplied. The presence of CO indicates a loss due to incomplete combustion, as the result of a deficiency of air or the improper mixing of air in the gases of combustion.

Sizing Stokers and Stoker Ratings

The capacity or rating of small underfeed stokers is usually stated as the burning rate in pounds of coal per hour. The *Stoker Manufacturers Association* has adopted a uniform method of rating stokers which is published in convenient tables and charts for selecting the size of stoker required.[3] The required capacity of the stoker may be calculated as follows:

$$\frac{\text{Load (Btu per hour)}}{\text{Heating value of coal (Btu per pound)} \times \text{overall efficiency of stoker and boiler or furnace}} = \text{Stoker burning rate required (pounds of coal per hour)}$$

In determining the total load placed on a stoker-fired boiler by a steam or hot water heating system, a piping and pick-up factor of 1.33 is com-

[3]Uniform Stoker Rating Code. Copies of this standard may be obtained from the *Stoker Manufacturers Association*, 307 North Michigan Ave., Chicago, Ill.